

EXPERIENCES OF ENGINEERING DESIGN FOR HIGH SCHOOL WOMEN

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Abstract This paper presents the experiences of teaching high school women during the 1991 Summer Study in Engineering Program. A project driven approach was employed in teaching the course to encourage talented women to pursue engineering careers. The course provided an introductory experience to the product development cycle by actually designing, building, and assembling a playground seesaw. Engineering concepts were taught in the classroom on an as needed basis during the design process. The students acquired computer skills through the preparation of technical reports and engineering drawings. The participating students were organized into groups and the aspects of teamwork and cooperative learning were highly stressed as the design project progressed. The women were motivated and satisfied with their academic achievements and personal development. Its impact on increasing enrollment of women students in engineering is far reaching.

1. Introduction

The development of technology and increasing competition in the 20th century challenge our educational system to provide the new generation with superior knowledge, skills, and realistic industrial experience. It has been a well-known fact that women are still under represented in science and engineering. Consequently, significant progress should be made to overturn this trend. Recognizing the strategic need for encouraging talented women to pursue engineering education in college, the University of Maryland has provided funding for high school women to study engineering in the summer. Twenty-one women students from three states participated in the 1991 program. Unlike the traditional teaching method by lecturing, we developed a new approach of teaching high school women. It focused on teaching engineering design through the project development cycle. The participating students were organized into four groups of 5 or 6 students each. Each group designed a playground seesaw based on the basic engineering concepts learned in the classroom. They used computers to prepare technical documents and engineering drawings. Finally, each group manufactured, assembled, and tested the designed seesaw.

In this paper, we present our experience in implementing this new engineering design course to the high school women. In section 2, we describe the basic course structure, and four major activities arranged in this course. In section 3, we present the students' outcomes with emphasis on their academic achievements, personal development, and preparation for college education. Section 4 summarizes the results and outlines its impact on increasing enrollment of women students to learn science and engineering.

2. Structure of the Engineering Design Course

Our main objective in developing this engineering design course is to provide the women students with the opportunity to learn an introductory experience to the product development cycle. We hope that such an experience would develop a positive attitude for engineering education in college by enabling them to understand what engineering is about and what an engineer does.

In order to create an environment for the participating students to learn the concepts of engineering design efficiently, a project driven approach is introduced. The design project involved the development of a playground seesaw, which was simple, yet sufficiently challenging, to motivate the students to learn basic engineering concepts. The design development process consisted of three stages, i.e., design, manufacturing, and assembly. By actually building the product, the students were exposed to the product development cycle, learned how to work as a team, and gained important hands on experience. The training of entry level skills of using computer application programs were also emphasized. We hoped that the project driven approach would motivate the high school women and help them to achieve a conceptual understanding of engineering design through an active learning process.

2.1 Arrangement of Activities

During the 1991 summer program, the design course was taught for six weeks. In each week, the class met three times. Each class period covered two hours and thirty minutes, and was divided into 50 minutes of lecture, 50 minutes of computer lab, and 25 minutes of group discussion. After class, the students were requested to spend five hours studying individually and/or working with their group members as a team. During the six-week program, each student devoted 135 hours to this course. The following list illustrates a general arrangement of the planned activities.

Listening to the lectures:	18 hours	13.3%
Working in the computer lab:	54 hours	40.0%
Studying individually:	27 hours	20.0%
Working on design project as a team:	36 hours	26.7%

Total: 135 hours		100%

2.2 Four Major Activities

2.2.1 Lecturing Basic Engineering Concepts To enable the women students to start the design process, basic but essential engineering concepts involved in the design of a seesaw should be clearly delivered to them. During the six-week program, we taught those concepts to the students through lectures. The eight basic engineering concepts selected are: 1) Free-Body Diagram; 2) Static Equilibrium; 3) Stress Analysis; 4) Strength of Materials; 5) Safety Factor; 6) Work and Energy; 7) Impact Effect; and 8) Engineering Drawings. These concepts were introduced to them on an as needed basis so that the students were able to perform engineering analysis related to the design of their seesaw. By acquiring these concepts, the students gained a comprehensive understanding of what engineering design is about and sensed the strong connection between theoretical concepts and engineering applications. As an example of learning the concept of free-body diagram, the students drew the free-body diagram for each of the components of the seesaw product during the design stage. They identified the acting forces and reactions on the component under investigation, and analyzed the conditions for maintaining its

static equilibrium to justify their decisions made during the design stage. To aid in the learning process, a set of lecture notes was distributed to the students and homework assignments were assigned to them. These homework assignments were composed of basic, intermediate, and high levels to ensure that the women students from high school were capable of adapting to the college environment. The assignments also promoted the development of their creative thinking skills in problem-solving. A mid-term examination and a final examination were given to evaluate their progress in learning the basic engineering concepts.

2.2.2 Project Driven Approach We believe that students at the high school level have, at least, intuitive ideas about engineering design, especially for a familiar product like seesaw. For example, the familiarity allowed them to define the product specifications and constraints with ease. In fact, they initiated their own designs by first imitating, then modifying the existing seesaws, and finally arrived at their own designs.

Common sense dictates that the design process involves creative thinking, application of modern technology, and economic considerations. A good engineering design not only ensures outstanding performance of the designed product, but also offers ease in manufacturing parts and facilitates the assembly operation. To follow this philosophy, we taught them that the engineering design of a product is a three-stage process, i.e. design, manufacturing, and assembly. We emphasized the importance of integrating the manufacturing and assembling stages because a design experience would not be completed without building the product and testing it to ascertain if it met the design specifications. Without going through the manufacturing stage of the piece parts and the assembly stage of its final product, the designer would not be able to justify his or her work.

During the teaching process, we expected questions from the students like "How does one design, manufacture, and assemble a seesaw product?" To effectively stimulate the students, we worked out a set of clear and detailed guidelines for the design, manufacturing, and assembly stages through group discussions. Figure 1 provides a list of the major tasks identified in the three stages. For example, to answer the question "How does one start the project of designing a seesaw?" We responded by asking the students to discuss what you could do and let the students work out a list of the tasks to follow. As a result, the students, working as a team, visited public playgrounds where seesaws were located to determine how different seesaws worked and what their primary components were. Table 1 presents the specifications of the seesaw design formulated by one group. It is evident that the completion of the first three tasks listed in Figure 1 enabled the women students to initiate their own design.

2.2.3 Learning Computer Skills As indicated in Fig. 1, at the end of each stage, we asked the students to summarize what they had accomplished. We requested them to prepare technical reports and engineering drawings using computers. Three computer application programs were selected and taught through practice and self-instruction with on-site assistance. They were 1) WordPerfect (word processing software); 2) Lotus 1-2-3 (spreadsheet software); and 3) AutoSketch (computer-aided design software). To our surprise, the students learned the computer skills with great enthusiasm. They spent many hours in the computer lab practicing their skills in using computers. Their accomplishment was far beyond our expectations. Figure 2 shows a typical general assembly drawing of a seesaw product prepared by one design group.

2.2.4 Manufacturing and Assembling When the students completed the product design, they took the responsibility for manufacturing and assembling the seesaw components. First, they went to local stores to purchase the raw materials needed. When they were at

the stores, they realized some of their component designs were unrealistic. For example, the standard dimensions of woods available at the store did not fit their needs. Before starting the component manufacturing, they had to modify their component

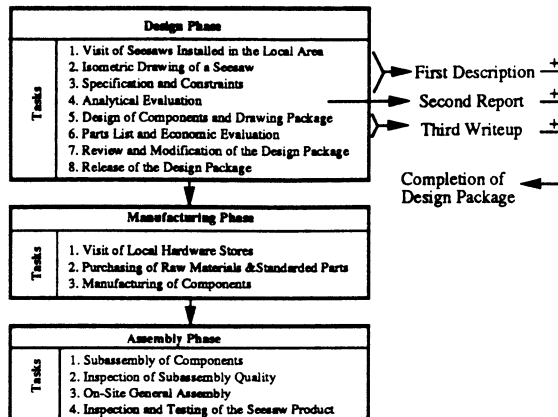


Figure 1 Major Tasks Involved in the Design, Manufacturing, and Assembly Stages

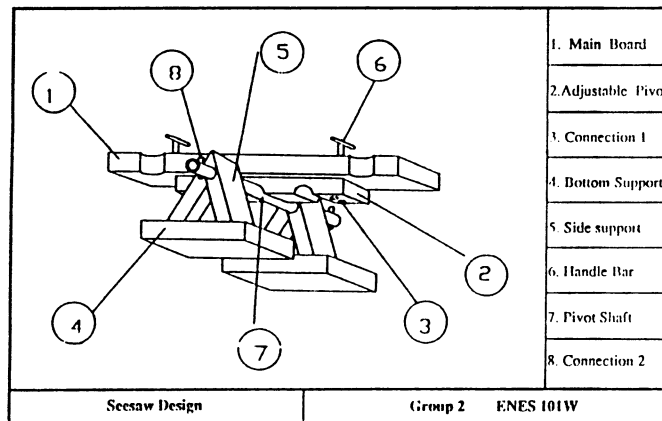


Figure 2 General Assembly Drawing of a Seesaw Product

designs to meet material availability and costs. During component manufacturing, the students had to learn skills associated with conventional hand tools such as saws, hammers, and drills. The students were eager to learn these practical skills even though some of them had previously never hammered a nail. Figure 3 shows the work space where the women students were busy manufacturing components. During the assembly and testing stage the students learned more work-related design experience such as the concept of tolerance and the importance of process planning. The students learned that the dimension of a hole should be larger than the diameter of a shaft which rotates inside the hole. When assembling the handle bars shown in Fig. 2, the students learned that the shoulders on the vertical bars should be made before the horizontal handles were attached to them. When the whole seesaw product was assembled, they sensed the importance of

Table 1 Design Specifications of the Seesaw

Users	For use by individuals of both sexes age 3 to 10 with a weight limit not to exceed 300 lbs.
Social Aspects	Capable of entertaining social groups of up to four children.
Space	Intended to be used by family units on their own property.
Assurance	Guaranteed to be safe, durable, easy to maintain, with good spare part availability, and low replacement cost.
Product Life	The anticipated life of the product is 10 years.
Assembly	Rudimentary assembly by the consumer.
Total Cost	The total cost not to exceed \$125.00

making a prototype during the product development cycle. The prototype suggested the changes necessary in the product design. One student said "It's amazing that you can learn so much from the design of an object as simple as a seesaw."

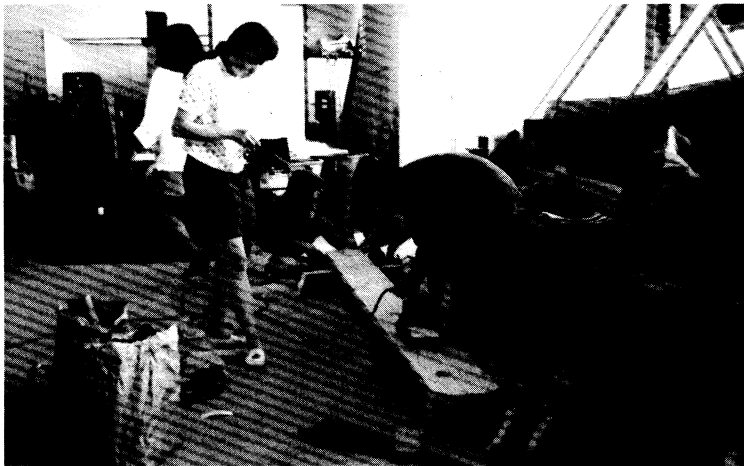


Figure 3 Women Students Working on the Shop Floor

3. Outcomes of Women Students

Our experience with the summer program has been extremely positive. We taught engineering design to the high school women through a project driven approach. While they were learning basic engineering concepts and computer skills, they applied these concepts into the design project. Three major outcomes are summarized as follows.

3.1 Academic Achievement

First they gained new knowledge in science and engineering. The general response from them was that the knowledge they gained is helping them tremendously in mathematics and physics in their senior year at high school. More important is that they have raised their academic standards. They liberate themselves from doing homework to seeking a better and deeper understanding of the concepts in mathematics, physics, and other subjects. The computer skills they learned during the summer program will prove helpful in the future. In fact, most of them have used these skills in preparing letters, essays, English papers, term papers, reports, and science fairs during their senior year.

3.2 Personal Development

The participating students achieved high personal development. The project-driven approach created a working environment to stimulate the students to a more advanced stage of cognitive development. On one side, the design experience met their developmental need for personal autonomy. They learned the skills to allocate time, money, and available resources. On the other side, peer-centered learning through team work offered them diverse experimental backgrounds and perspectives. When they related a design effort with a team effort, they brought different interests and views and began to work together. During the group decision making process, the important skills of patience and compromise had to be developed. They understood the social and technological systems, and strengthened their personal qualities that foster discipline, self-confidence, and the ability of working with others. At the end of the summer program, the students learned that "It would be impossible to satisfactorily complete the project without team work". One student remarked that "We gained knowledge from each other as well as made friends."

3.3 Preparation for College Education

The satisfaction of their academic achievements and personal development has encouraged the participating women to pursue college education after the graduation from high school. They felt more prepared for college because they knew what to expect from college courses and what it would be like to manage their time for studying. One student remarked that "The knowledge I gained over last summer proved to be useful in my senior year. Over the summer I learned how to analyze material. The course I took taught me how to think. Many times high school material does not require one to think. I feel more prepared for college now that I have experienced it at the University of Maryland. The summer program was set up and run very effectively. Although many times I became frustrated with the work, I think that it was good for me because it gave me a true taste of the school work at a college level. I enjoyed the course because it was difficult, and because I was challenged by it". We also received very positive responses from the students' parents. Since the 1991 summer program, we have received letters and phone calls to inquire about information related to the engineering programs available at the University of Maryland and at other universities. Quite a few parents visited us and discussed about their children. To our surprise, 50% of the participating students have indicated that they would major in engineering. Three students indicated that they would major in biology and chemistry.

4. Conclusions

In a six week summer program, we offered an introductory engineering science to twenty-one high school women. Using a project driven approach, we taught them engineering design through the product development cycle, i.e., actually making a prototype of a playground seesaw. The women students learned engineering fundamentals and computer skills, developed critical thinking skills, and had an educational experience that is relevant to their future need. They gained a better understanding of what is engineering and have fostered a positive attitude towards engineering.

Acknowledgments: Special thanks is due Dr. Marilyn Berman, Associate Dean of the College of Engineering. Her firm support of this program made this effort possible. The authors also appreciate the support from Drs. K. Mohrman, T. Regan, and W. Fournery, and the financial support from NSF ECSEL and CDF 8803012.